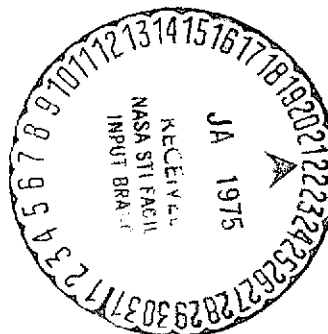


CATHODIC PROTECTION

Anonymous

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May 25, 1971 (letter, article and references), 6 pp.



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16. Abstract After its initial adjustment period, the Rance River tidal power plant has attained a down time ratio of only 4.8%. This low figure has been due in large part to the effectiveness of the cathodic protection used to shield the plant's submerged metal parts from corrosion, decreasing the necessity for repainting. The basic principles of cathodic protection are given briefly, followed by a more detailed description of how it is used on the Rance River equipment.			
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Books Dealing With the Rance River Tidal Power Plant

- * Gibrat, R., "L'Energie des Marees" [Tide Power], 1966, 219 pp. Presses Universitaires de France, 108 Blvd. St-Germain, Paris (6°).
- * La Rance (an extensive unpublished study), Revue Francaise de l'Energie, No. 183 (special), (September-October 1966). Les Editions Techniques et Economiques, 3 rue Soufflot, Paris (5°), 236 pp.
- * Six Years of Utilization of the Rance River Tidal Power Plant, La Houille Blanche, No. 2-3/1973 (special), 153 pp. La Houille Blanche, B.P. No. 356, 38008 Grenoble Cedex.

Journal Articles on the Rance River Plant

- (C.E.) Mauboussin, G., "The Rance River Tidal Power Plant," Suppl. aux Annales de l'Institut Technique du Batiment et des T.P., No. 199-200, 837 (July-August, 1964). 9 rue de la Perouse, Paris (16°).
- (C.E.) Mauboussin, G., and Duhoux, L., "The floodgates of the Rance River tidal power plant," Revue Generale des Techniques "Le Genie Civil", No. 17, 304 (September 1, 1964). 79 Champs Elysees, Paris (8°).
- (C.E.) Mauboussin, G., and Souille, G., "Excavation of the Rance River for construction of the tidal power plant," Revue Generale des Techniques "Le Genie Civil", No. 18-15, (328) (September 15, 1964). 79 Champs Elysees, Paris (8°).
- (E.M.) Auroy, F., "Bulb units in hydroelectric systems," Suppl. aux Annales de l'Institut Technique du Batiment et des T.P., No. 203, 1425 (November 1964). 9 rue de la Perouse, Paris (16°).
- (E.S.) Allary, R., "The Rance River Tidal power plant," La Technique des Travaux, No. 1-2, 22 (Jan.-Feb. 1966). 54 rue de Clichy, Paris (9°).
- (E.S.) Clair, H., "Electricity from the Ocean," Revue des Applications de l'Electricite, No. 213 (2nd trimester 1966). Sodel - 336, rue St.-Honore, Paris (1er).
- (E.S.) Auroy, F., "The Rance River tidal power plant," Revue Generale de l'Electricite, No. 7-8, 983 (July-August 1967). 16 rue Franklin, Paris (16°).

*Recommended.

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(C.E.) Mathieu, G., "The Rance River tidal power plant; Final assembly," Construction, No. 7-8, 269 (July-August 1967).
Dunod - 92 rue Bonaparte, Paris (6°).

(E.M.) Ferdinand, M., et al., "Control and monitoring of the Rance River tidal power plant," Automatisme, 17(142), 5 (January-February 1972). Dunod - 92 rue Bonaparte, Paris (6°).

(C.E.): Article dealing with civil engineering.

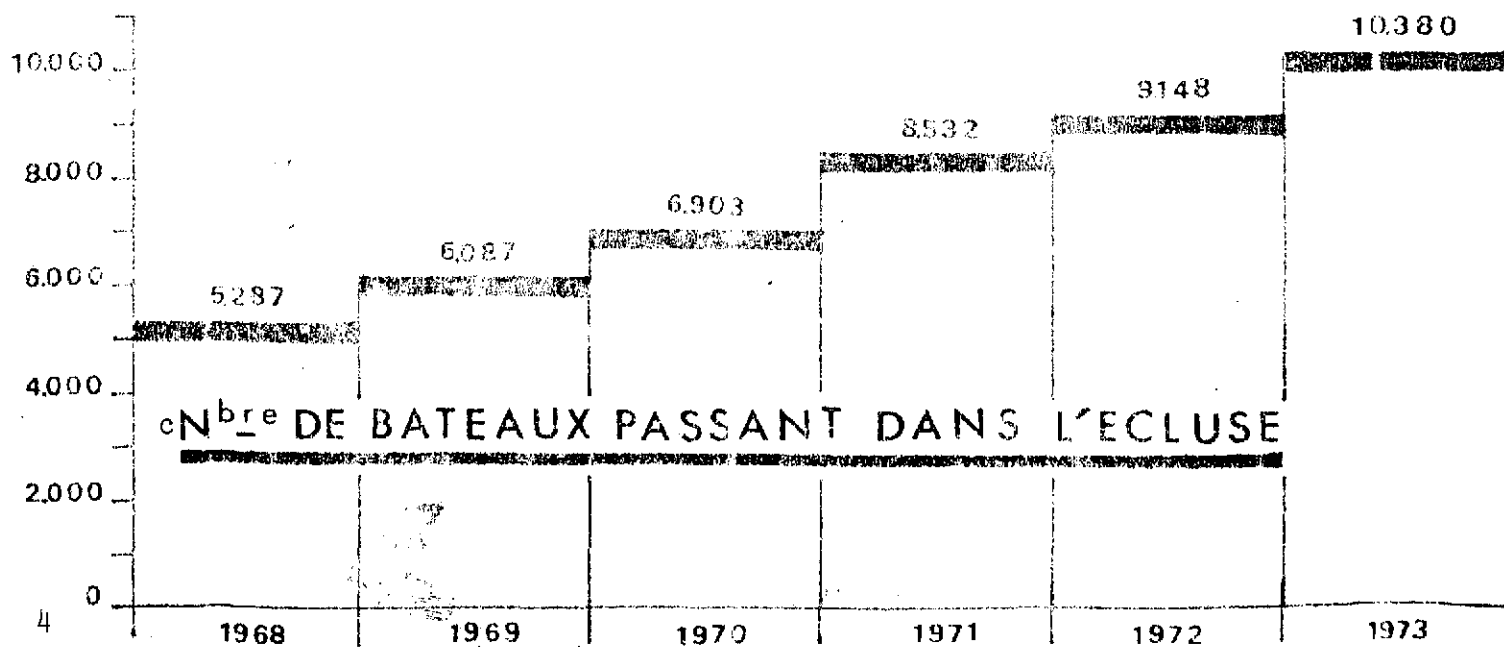
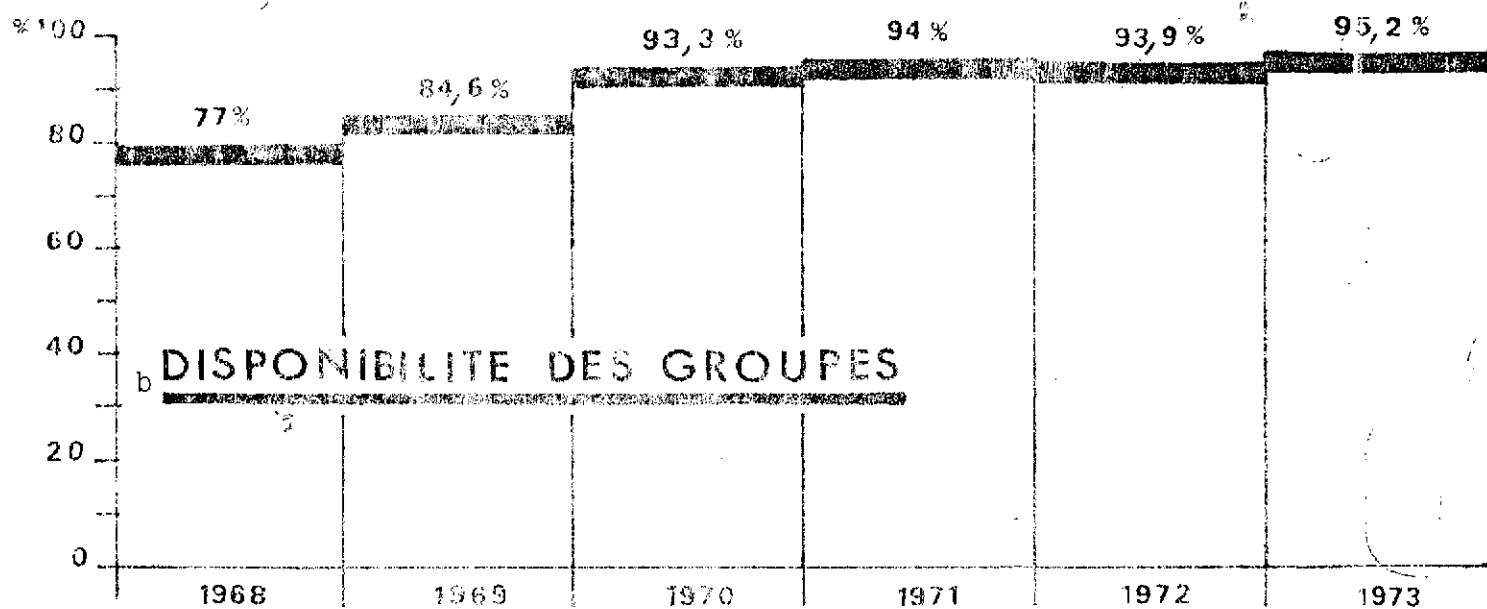
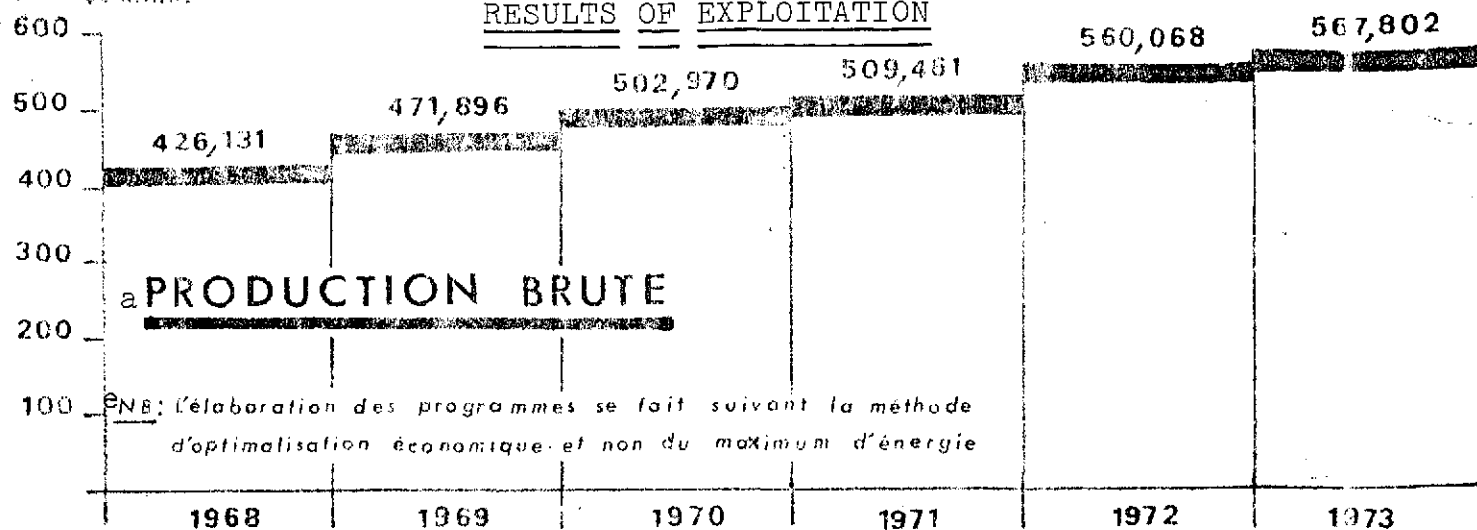
(E.S.): Article dealing with the plant as a whole.

(E.M.): Article dealing with the electromechanical part alone.

Key for charts (see following page):

- a. Gross production.
- b. Up time of units.
- c. Number of ships entering locks.
- d. Million kWh.
- e. N.B.: The programs are prepared by the economic optimization method rather than the maximum power method.

RESULTS OF EXPLOITATION



Results of Utilization of the Rance River Tidal Power Plant

An examination of the results of utilization of the Rance River tidal power plant after several years of service shows that the plant has fully lived up to expectations.

Since its 24 "bulb" units were put into operation (the last one in December 1967), the Rance River tidal power plant has generated more than 3.5 billion kWh, an amount approximately equal to the power consumption of the Ille-Vilaine sector over six years.

Many of us have heard about the "side benefits" of the Rance River plant, but many still do not know that, among other factors, the saving for the French power system resulting from the use of "bulb" units alone, especially on the Rhone and Rhine rivers, already amounts to half the investment for the Rance River plant. From a strict bookkeeping standpoint these side benefits should not be included as a factor in the economic feasibility of the plant; nevertheless the latter can no longer be open to question. The cost of operation per kilowatthour is less than the average cost of operation of French hydroelectric plants.

It is interesting to note that the number of vehicles using the dam road is on the order of 500,000 for a single month during the vacation season. This project has made it possible to decrease the distance between Dinard and St.-Malo by 4/5ths.

Subsequent to the developmental period following any plant startup, especially where a prototype is involved, the down time ratio has been only 4.8%. This figure is especially significant if one notes that it includes the entire amount of time necessary for the maintenance which is usually performed between periods of energy production. Taking the operating periods alone into account, this ratio decreases to 1.5%.

It should also be noted that there is no problem of sand coating at this plant.

We are pleased to be able to state that the units are still intact after an average of 60,000 hrs of immersion in seawater, due to the use of particularly effective cathodic protection.

These positive results are undoubtedly related to the quality of the preliminary research performed and to the reliability of the exclusively French equipment used in this plant.

It may be noted that the average number of ships entering the locks has increased by 1,000 per year. This is probably not unrelated to the fact that the water level in the basin is frequently lowered to approximately 1/3 of its value prior to the excavation of the Rance River, and to the facts that the currents are less strong and that the Rance River estuary becomes a splendid lake at some periods of the day.

Thus the French may be justly proud of their "first tidal power plant in the world," which currently remains the only one of its kind in France due to the fortunately competitive nature of nuclear power, -- but who knows? Let us not forget that this is a non-polluting energy source which is not affected by dry years and which does not depend on foreign supply.

Cathodic Protection

/1*

The protection of metal equipment against the attack of corrosion is a major concern in maintaining equipment immersed in seawater. After lengthy and extremely extensive research, three protection techniques were chosen for use at the Rance River plant for maximum limitation of damage due to corrosion; the use rust-proof metals (aluminum bronze, stainless steel), vinyl paint base

*Numbers in the margin indicate pagination in the foreign text.

coatings and cathodic protection. Five years of experience have shown that, for immersed metal equipment permitting an appropriate electrical field distribution, cathodic protection yields excellent results and obviates the deficiencies of other protection systems. The purpose of this report is not to present cathodic protection theory nor to determine the characteristics of the installations, but to give the results of utilization after a few years of actual service.

After a brief review of the basics of cathodic protection, the characteristics of the devices installed at the Rance River plant will be outlined and the overall utilization results will be given.

1. Basic Principles

The phenomenon of corrosion is linked to the production on metal surfaces of differences in electrical potential which, in combination with an electrolyte, permit the transfer of metallic ions from the less noble to the more noble metals. These differences in potential and in the level of the resultant current depend on a number of factors such as the nature of the metals present, surface condition, mechanical stresses, previous mechanical and thermal treatments, impurities in the metals, and physico-chemical variations in the electrolyte.

These natural corrosion currents may be neutralized by introducing a direct current which passes through the electrolyte from an anode to the part to be protected, which becomes a cathode. The negative ions such as chlorine collect at the anode and lose their charge, while the cathode collects the positive ions such as calcium or magnesium. The part to be protected is cathodically polarized; this is the basic principle of cathodic protection by an imposed current. Various studies have shown that in order to pro-

tect carbon steel, the metal must be placed at a voltage of between -850 and -1200 mV in comparison to a silver chloride reference electrode. The voltage is limited to ± 1200 mV to avoid increasing the rate of blistering of the paint layers.

2. Cathodic Protection Devices Used in the Rance River Plant

Cathodic protection is currently being used on three types of equipment:

- the units, since they were first put into operation (1966);
- the watergates, since March 1968;
- the lock gates, since March 1970.

These systems have been studied by the French Department of Tests and Protection of Gasworks, whose specific activity is the research and development of corrosion protection for underground and submerged equipment.

/2

2.1. Units

From the beginning, the 24 tide engine units were designed with cathodic protection, as a result of extremely satisfactory tests performed on the experimental unit installed at St.-Malo. (See the special issue of the Journal of the French Hydrotechnical Association, Supplement No. 2-1962, Houille.)

Each unit consists of three rings of 12 anodes each:[1];

- one ring on the wheel mantle located on the seaward side;
- one ring on the distributor;

-- one ring on the cap of the tie-beam ring and the access lever.

These rings protect the ordinary steel parts, and the first two neutralize any induction coupling set up between the ordinary steel and the rustproof metal.

A silver chloride voltage tap makes it possible to monitor the voltage of the protected surface for each ring.

Rings of the same type are powered in parallel for four units by a single 24-V, 120 A rectifier, with voltage regulator resistors on three of the four rings.

Thus for a system of four units there are three rectifiers whose positive polarity is linked to the anodes and whose negative polarity is linked to the bodies of the units.

The anodes, which are in the form of ~~a valve~~ 50 mm in diameter, consist of a platinum-coated tantalum disk (thickness 50 μ m) welded onto a tantalum rod. The assembly is kept in place by a polyethylene part fitted into a housing on the part being protected. Tantalum was chosen due to the large voltage difference of its oxides, which would counteract destruction of the part if the platinum should disappear; thus the risk of an influx of water through the housing of this rod is reduced to a minimum (a fact which is very important for the inside of the bulb). An extra-high thickness of 50 μ m was chosen to allow for mechanical wear and tear; for testing purposes, 5 μ m platinum anodes have been installed in two units. It should also be noted that the platinum is altered by alternating current, resulting in the necessity for periodic monitoring of the operating characteristics of the rectifiers.

2.2. Floodgates

Cathodic protection was installed on the floodgates after the dam had been put into operation. Each 15 x 17 m floodgate has an ordinary steel apron, but the rails are stainless steel. To preclude induction coupling, the journals of the rollers are electrically insulated from the apron. These provisions were made before the possibility of installing cathodic protection had been envisioned.

For each floodgate, four anodes are affixed to the side-wall:

- on the right and left banks of the seaward side;
- on the right and left banks of the basin side.

(1) To polarize an unpainted unit at -1000 mV, the density must be on the order of 250 mA/m^2 for stainless steel and 150 mA/m^2 for carbon steel.

A 24 V, 40 A rectifier powers the anodes on the seaward side /3 of a given floodgate, and another identical rectifier those on the basin side. Two voltage taps make it possible to monitor the polarization of the protected metal on the seaward and basin sides. The anodes are platinum-coated titanium tubes 1.43 m long and 25.5/23/5 mm in diameter attached to the sidewalls 1 m from the apron and approximately 13 m from the floodgate.

2.3. Locks

Each lock-gate consists of two sector leaves 11.3 m high and with a development of 8.8 m (external area 125 m^2 , internal area approximately 350 m^2 , current density used 150 mA/m^2).

The anodes are identical to those of the floodgates.

For each lock-gate there are;

-- inside the chamber, six anodes attached to the invert, three on the right bank and three on the left bank, placed at an average distance of 25 m from the center of the gate.

-- on the outside, two anodes, one on the right bank and the other on the left bank, located at distances of between 30 and 50 m.

The anodes of a given gate are powered:

-- by a 20 V, 120 A rectifier in the chamber;

-- outside the chamber, by a 20 V, 40 A rectifier.

To preclude excessive polarization of the lower parts, the rectifiers are shut off until the submerged height of the gates is less than 3 m.

3. Utilization

3.1. Periodic Controls

After the testing and adjustment period, the following measuring methods were used:

-- Unit:

Every month

After at least one hour of direct operation (emptying of basin), measurement of voltages and current in one anode by ring).

Every Three Months

Measurement of current in all anodes.

-- Floodgates and Locks;

Every Month

Measurement of voltage and current of each anode.

Every half year, testing of the wave shape of the rectified current from all rectifiers.

3.2. Problems

With reference to the units, about ten anodes (out of 864 anodes in service) lost their platinum-coated tantalum disk, due either to a defect in [word illegible] or to impacts with foreign objects.

With reference to the floodgates, two anodes were twisted due to passage of a foreign object.

4

Two failures were noted in the voltage taps.

Apart from these minor problems, the performance of the equipment as a whole was entirely satisfactory.

3.3. Results

Units

Nearly five years after the first machines were put into operation, it may be noted that a good deal of the paint has disappeared from the wheel mantles, the distributor and the tie-beam sheaths; on the rest of the equipment the coating has disappeared in a few patches. The unprotected metal is covered with a whitish calcium and magnesium salt deposit, but is not corroded. This deposit is hard when it is primarily calcium-base, and soft and gelatinous when there is considerable magnesium (too strong a polarization). Around the anodes an incipient chloride attack may be noted which is greater as the ability of the gas to escape

decreases (downward-turned cavity). Due to the disappearance of the paint it was necessary to increase the flow from the rectifier in order to avoid a voltage imbalance, but a large part of the current reaches the cathode in the immediate vicinity of the anode. To lessen these two phenomena, in November of 1970 we performed a test on a few anodes from Unit A.1 which consisted in surrounding them with a thick layer of epoxy cement (1 mm) over an area of 50 x 50 cm.

Floodgates and Locks

As with the units, the steel which is laid bare is protected by and covered with a calcium-magnesium deposit. The lock-gates, repainted in November 1967, began to corrode one year later, since it was impossible to reconstitute conditions as favorable as those occurring when the dam was being built. Development of the corrosion has stopped since the protection was put in service.

3.4. Cost

The cost of protecting the lock equipment will be taken as an example.

Partial repainting of the metalwork of the locks at the end of 1967 cost more than 100,000 F; in 1968, however, rust reappeared on some parts of the lock-gates and floodgates. Since March 1970, when the cathodic protection was first put into service at a cost on the order of 100,000 F, the process of corrosion has been checked with an average power consumption of 150 W for all the submerged equipment of the locks.

The power used by the protection systems for the plant as a whole is less than 10 kW.

Conclusions

After five years of use, it may be stated that cathodic protection plays an essential part in the satisfactory operation of the tidal power plant, effectively protecting carbon steel and eliminating the pitting phenomena noted in some types of stainless steel in seawater, for a total quantity of some 12,000 tons of metal submerged in seawater. This protection permits a considerable decrease in the frequency of repainting operations, contributing to a decrease in down time and resulting in an increase in the energy produced by the Rance River tidal power plant.